Danish Research Service for Plant and Soil Science
Research Centre for Horticulture
Institute of Pomology
DK-5792 Årslev

Report no. 2014

Ten years results with apple rootstocks M27, M9, and M26 at two spacings

Ti års resultater med æblegrundstammerne M27, M9 og M26 på to planteafstande

OLE CALLESEN

Summary

Results of a comparison of the rootstocks M26, M9 and M27 are described. The scion cultivars used were 'Spartan' and 'Summerred'. The relative vigour between the three rootstocks briefly confirm the data given in the literature. After ten years the highest yields were obtained on M26, although the cropping efficiency was higher for the weaker rootstocks for one of the cultivars.

However, the high efficiency on M27 and M9 still cannot compete with the rapid volume build-up on M26. The largest fruit size was found on M26 and M9 and the colour development was best on M27, while M9 and M26 were equal. Under the soil, climatic and scion vigour conditions for this trial M26 is recommended as superior to M9 and M27.

Key words: Apple, burrknots, fruit quality, spacing, 'Spartan', 'Summerred', yield.

Resumé

Sammenligning af æblegrundstammerne M26, M9 og M27 er beskrevet. De anvendte sorter var 'Spartan' og 'Summerred'. Relativ vækstkraft mellem grundstammerne bekræfter i store træk, hvad andre har fundet, dog ses nogle sortsforskelle. Efter 10 år var de største udbytter med begge sorter opnået med grundstamme M26, selv om træernes produktivitet var større på de svagere grundstammer for 'Summerreds' vedkommende, men dette var dog ikke nok til at konkurrere med det større trævolumen, der hurtigere blev opnået med M26.

Frugtstørrelsen var størst med M26 og M9, og frugtens farveudvikling var bedst med M27, mens M9 og M26 havde samme frugtfarve. Under de jordbundsforhold, det klima og med den vækst, de anvendte sorter giver, må M26 anses for bedre end M9 og M27.

Nøgleord: Frugtkvalitet, planteafstand, 'Spartan', 'Summerred', udbytte, æble.

Introduction

Earlier M9 and M26 have been tested under Danish conditions, and compared with several M and MM stocks (5). M26 was prefered for dense plantings, because its yields were higher and the fruit size as good as that obtained on M9. *Preston* (8) showed that M9 and M27 were the most efficient rootstocks concerning ratio of crop to scion fresh weight. In high density orchards it should be easier to exploit the efficiency of the weakest rootstocks. It was therefore decided to test the most promising rootstocks for high density plantings at two densities, which should include the interaction between vigour and density. M27, M9 and M26 were chosen for this investigation at the densities 1428 and 2856 trees per ha.

Materials and methods

A rootstock trial with M27, M9 and M26 was planted in spring 1979 using two-year old trees. The cultivars 'Summerred' and 'Spartan' were planted with a row distance of 3.5 m and on the in-row distances 1 and 2 m. The soil was sandy loam with a clay content of 11–15%. The trees were staked and pruned as slender spindle and were allowed to grow to a height of about 2.5 m. Soil management was non tillage kept clean with herbicides. The trunk circumference was measured 25 cm above the union, which was placed 10–20 cm above the ground. Fruit thinning was done most years to a fruit density recommended for commercial production of the cultivars.

Fruit colour was determined by a MAF electronic colour sorter, which take four readings per apple.

Results

Yield and fruit quality

'Spartan'

From the third year significant differences were found among rootstocks. For all the years, except 1986, trees on M26 yielded more than on M9 and M27, Table 1, at both 2856 and 1428 trees per ha. From the fourth year (1982) M9 yielded more than M27 at both densities. With 2856 trees per ha the total yield for M9 was 81% of that of M26, and for M27 this was 50% only. For the wider spacing the ratio was 100, 65, and 31 respectively, Table 1. There was a significant effect of the tree density on the yield and for all rootstocks the highest density gave the highest yield.

The fruit size seemed to decrease with the increasing age of the trees, Table 3, however, the favourabel weather for fruit size development in 1988, again restored a good fruit size. In four years fruit size differed significantly among rootstocks with M26 giving the biggest fruits. In most years M27 produced smaller fruits. There was a clear reduction in the fruit size at the highest density.

The fruit surface colour was generally good. In Table 4 it can be seen that about 90% of all 'Spartan' fruits was more than 75% red. There was a tendency to better colour on rootstock M27. Expressed as tons fruit per ha bigger than 60 or 70 mm with more than half of the surface red, M26 gave the highest yields, and still the highest density gave the highest yields.

'Summerred'

Also for 'Summerred' significant differences occurred among the rootstocks after three years.

Table 1. Yield buildup for 'Spartan' on rootstocks M27, M9 and M26 at two densities. Tons per ha.

Rootstock	Density	Year									Total
		1980	1981	1982	1983	1984	1985	1986	1987	1988	
M27	2856	2	16	16	25	21	21	20	13	28	161
	1428	1	8	5	10	12	11	10	8	16	82
M9	2856	2	21	31	38	43	30	33	21	41	260
	1428	1	11	20	26	32	19	21	15	26	170
M26	2856	4	32	44	48	49	38	35	24	48	321
	1428	3	15	34	42	35	36	36	24	36	261
LSD (stock)		NS	7.7	4.6	4.8	–	4.0	5.8	2.9	4.7	–
LSD (dens.)		NS	6.3	3.8	3.8	–	3.3	4.6	2.3	3.8	–

Table 2. Yield buildup for 'Summerred' on rootstocks M27, M9 and M26 at two densities. Tons per ha.

Root-stock	Den-sity	Year									Total
		1980	1981	1982	1983	1984	1985	1986	1987	1988	
M27	2856	5	9	11	16	17	15	14	10	14	110
	1428	2	4	4	8	10	10	8	5	8	57
M9	2856	6	16	13	30	39	28	24	15	27	199
	1428	4	10	8	20	24	15	13	9	15	118
M26	2856	10	28	21	38	39	43	42	23	41	285
	1428	3	14	6	25	26	25	23	16	22	160
LSD (stock)		5.1	2.5	NS	10.8	–	5.3	4.1	2.8	3.3	–
LSD (dens.)		4.2	2.1	8.4	7.5	–	4.4	3.3	2.3	2.7	–

Table 3. Fruit size as g/fruit for 'Spartan'.

Rootstock	1980	1981	1982	1983	1985	1986	1987	1988	Mean
M27	157	126	130	110	114	105	100	127	121
M9	163	145	138	117	106	111	99	139	127
M26	154	166	137	127	111	109	95	138	130
LSD	NS	3.6	4.7	2.4	6.6	NS	NS	8.7	–
Trees per ha									
2856	158	140	130	114	107	104	96	129	122
1428	159	152	140	122	117	116	102	143	131
LSD	NS	3.0	3.8	2.0	5.4	6.3	3.7	6.9	–

Table 4. Colour development on 'Spartan'. Figures are mean of 1985, 1986, and 1988. The percentages are calculated on total yield. Fruit size lower than 55 mm is not included in colour grading.

Rootstock	Surface colour			Tons/ha with more than 50% colour	
	under 50%	50–75%	over 75%	over 60 mm	over 70 mm
M27	1	3	95	15	6
M9	2	8	88	24	13
M26	2	11	86	35	18
Trees per ha					
2856	2	8	88	28	13
1428	1	7	91	20	11

Even after ten years M26 still yielded more than M9 and M27 at both densities. M9 yielded more than M27, too. With 2856 trees per ha M27 and M9 yielded 35% and 69% of M26, and with 1428 trees per ha M27 yielded 36% and M9 74% of that of M26, Table 2. For 'Summerred' the lowest density only yielded 57% of the highest density for the ten year period. Fruit size on 'Summerred' seemed to decrease with the tree age. In the first three cropping years, M9 produced the biggest fruits, but in the last five years M26 produced the biggest fruits, whereas M27 gave the smallest

Table 5. Fruit size as g/fruit for 'Summerred'.

Rootstock	1980	1981	1982	1983	1985	1986	1987	1988	Mean
M27	136	124	133	121	121	87	89	118	116
M9	142	139	160	145	101	91	87	131	125
M26	140	135	145	147	110	99	97	135	126
LSD	1.2	3.6	8.2	2.7	12	5.8	4.0	4.5	–
Trees per ha									
2856	135	131	141	133	114	93	89	125	120
1428	144	135	151	142	106	91	96	132	125
LSD	1.0	3.0	6.7	2.2	NS	NS	3.3	3.7	–

fruits in all the years except 1985, Table 5. In most years the most dense planting resulted in the smallest fruits.

Also for 'Summerred', M27 gave the best colour development. The highest density gave less colour than the wider tree spacing, Table 6. Expressed as tons fruit per ha with more than 33% or 66% colour and a size bigger than 60 mm, M26 gave the highest yields, at both planting densities.

Table 6. Colour development on 'Summerred'. Figures are mean of 1985–88. The percentages are calculated on total yield. Fruit size lower than 60 mm is not included in colour grading.

Rootstock	Surface colour			Tons/ha more than 60 mm	
	under 33%	33–66%	over 66%	over 33% colour	over 66% colour
M27	1	8	77	9	8
M9	3	16	65	14	11
M26	3	20	71	24	19
Trees per ha					
2856	3	16	67	20	16
1428	2	14	75	11	9

Tree vigour

The trunk circumference on 'Spartan' after nine seasons was 100%, 65% and 52% for M26, M9 and M27 respectively, Table 7. Tree diameter, height and tree volume differed among the rootstocks, although the trees were pruned, Table 9.

Table 7. Growth measurements after growing season 1987 for 'Spartan'. Trunk circumference (mm), tree height and diameter (cm). Mean of densities.

Root-stock	Circumference		Tree diameter	Tree height
	mm	relative		
M27	114	52	142	241
M9	144	65	176	278
M26	221	100	208	288
LSD	19		15	17

Table 8. Growth measurements after growing season 1987 for 'Summerred'. Trunk circumference (mm), tree height and diameter (cm). Mean of densities.

Root-stock	Circumference		Tree diameter	Tree height
	mm	relative		
M27	89	55	92	164
M9	118	73	120	213
M26	162	100	156	245
LSD	13		9	55

The relative vigour of M9 was about the same when measured as trunk circumference and tree volume, but for M27 the measured volume gave lower vigour as expected from the circumference measurements.

Trunk growth was weaker for 'Summerred' than for 'Spartan'. However, the relative differences was about the same, Table 8. Also for 'Summerred', tree diameter, height and tree volume differed significantly between rootstocks after nine years, with M26 giving the double volume of M9 and with M27 giving 22%, only, Table 10.

Table 9. Tree volume after 9th season for 'Spartan'.

Rootstock	M27		M9		M26		LSD
Trees/ha	2856	1428	2856	1428	2856	1428	
m^3/tree	1.05	1.20	1.75	2.60	2.48	3.79	0.52
m^3/ha	3009	1716	4995	3313	7075	5407	1234
relative	38		67		100		

Table 10. Tree volume after 9th season for 'Summerred'.

Rootstock	M27		M9		M26		LSD
Trees/ha	2856	1428	2856	1428	2856	1428	
m^3/tree	0.32	0.27	0.65	0.75	1.26	1.47	0.26
m^3/ha	915	378	1858	1075	3587	2095	731
relative	22		51		100		

Tree efficiency

Both the accumulated yield and the yield of the last three years related to the trunk size in 1987, showed the highest values for M9 and M26 at the widest spacing for 'Spartan', Table 11. The fruit yield per m^2 tree canopy was about the same for all rootstocks except for M26, which had a higher productivity at the widest spacing, Table 11. Measured per tree volume M26, and M27 at the widest spacing yielded more than other combinations in the last three years, while there was no differences between rootstocks and densities for the whole production period, Table 11.

Productivity for 'Summerred' measured as kg per cm trunk circumference for the whole period or for the last three years showed the lowest productivity for M27 and about the same for M9 and M26, Table 12. Measured as production per m^2 canopy over the last three years, no significant differences among the rootstocks were detected.

Table 11. Canopy efficiency measured on trunk girth (kg/cm) tree spread (kg/m^2) and volume (kg/m^3) for 'Spartan'.

Root-stock	Den-sity	kg/cm 1979–87	kg/cm 1985–87	kg/m^2 1985–87	kg/m^3 1979–87	kg/m^3 1985–87
M27	2856	4.1	1.8	13.7	44	19.8
	1428	4.0	1.9	13.2	38	21.5
M9	2856	5.6	2.3	14.4	44	18.1
	1428	6.4	2.5	12.4	44	16.6
M26	2856	4.6	1.7	12.7	39	15.5
	1428	6.6	2.9	16.1	41	20.5
	LSD	–	0.3	2.9	–	4.5

Table 12. Canopy efficiency measured on trunk girth (kg/cm) tree spread (kg/m^2) and volume (kg/m^3) for 'Summerred'.

Root-stock	Den-sity	kg/cm 1979–87	kg/cm 1985–87	kg/m^2 1985–87	kg/m^3 1979–87	kg/m^3 1985–87
M27	2856	3.8	1.6	22	105	57
	1428	4.1	1.9	28	136	70
M9	2856	5.5	2.3	25	92	43
	1428	5.7	2.3	22	96	49
M26	2856	5.6	2.5	22	68	33
	1428	5.7	2.8	22	65	33
	LSD	–	0.4	NS	–	18

M27 was the most productive as to its volume with about the double of M26. This was the case whether the last three years or the whole period were considered, Table 12. M26 was the least productive as to its volume for 'Summerred'.

Burrknots

All three rootstocks produced burrknots, and for both cultivars M26 had significantly more burrknots than the other rootstocks and with no difference between M27 and M9. The union was not exactly at the same height for all trees. Therefore, the number of burrknots is shown as number per 10 cm of rootstock above the ground, Table 13. This method still shows most burrknots on M26.

Table 13. Number of burrknots per tree 1987 for 'Spartan' an 'Summerred'.

Root-stock	Burrknots per tree		Burrknots per 10 cm rootstock	
	'Spartan'	'Summerred'	'Spartan'	'Summerred'
M27	2.7	3.1	1.9	2.3
M9	3.2	2.9	2.8	2.1
M26	5.5	7.1	3.4	3.6
LSD	0.9	1.0	0.7	0.7

Discussion

Yield

With the same number of trees per ha for different rootstocks, yield differences will be found because of different tree sizes. *Christensen* (5) has shown that kg per tree over a range of rootstocks is relatively close related to the trunk size. In this investigation the highest yields were found for the most vigorous rootstocks even at a density of 2856 trees per ha. However, for 'Spartan' on M26 at either density yield was the same from the seventh to the ninth year, indicating that also trees at a density of 1428 trees per ha had produced as efficient a canopy as the trees at the higher density. This was not the case for the other rootstocks.

The smaller fruit size on M27 for both 'Summerred' and 'Spartan' is a problem under Danish conditions where undersized fruit is a general problem. In work reported by *Scholtens* (9) M27 gave smaller fruits than M9 and M26 for 'Gloster', but not for 'Jonagold' or 'Melrose'. For 'Starking Supreme Delicious' *Autio* (1) found a decreasing fruit size from M9 to M26 and M27. The reduced fruit size on M27 may in some cases be caused by a poor leaf/fruit ratio due to almost no growth. In this experiment the higher fruit density on M27 for 'Summerred' indicates overcropping, which reduces fruit size.

The better fruit colour development on M27

may not be profitabel, because of the poor yields on this rootstock.

Vigour

'Summerred' grown as bush trees on semivigorous rootstocks as MM106 is considered a semivigorous cultivar, but when grown as spindle trees on dwarf rootstocks as M9 and M27 it is a relative weak cultivar. This may be caused by early cropping and a high yield on one year old wood (3), which bend the branches much below horizontal and reduces tree volume.

In this investigation M9 has a vigour on 65–73% of that of M26, when measured as trunk size. This is a little weaker than the 69–81% *Wertheim* (10) found for 'Golden Delicious' and 'James Grieve'. The found vigour for M27 was 54–66% of that of M26, which is in good agreement with *Wertheim* (10).

Relative vigour measured as tree volume of M27 and M9 was lower than the trunk size suggested. *Preston* (8) mentioned M27 to be about half of the size of M9 for bush trees, which is supported by these findings for spindle type trees. The very dwarf appearance on a volume basis may be explained by the more open tree canopy and lower trees on M27 and M9 than M26. This may also be part of the explanation for the lower yields on M27 and M9. A similar result was found by *Callesen* and *Christensen* (4) in a comparison of M26 and MM106 for 'Summerred' with 1900 trees per ha where MM106 outyielded M26 without a decrease in the fruit quality, and without that the more vigorous growth on MM106 resulted in problems with fruit colour and heavy pruning.

Tree efficiency

The lower productivity related to the trunk size for M27 is supported by the results with 'James Grieve' and 'Golden Delicious' reported by *Wertheim* (10). However, *Autio* (1) found no differences in the productivity among the three discussed rootstocks for 'Starkspur Supreme Delicious'. A comparison between M26 and M9 for 'Golden Delicious B' gave a higher yield on M26, but the highest volume efficiency on M9, while the production per m^2 was the same (2). This is supported by the present results. Tree efficiency measured as accumulated yield on the final tree size showed remarkable differences between the two cultivars. The last three years may be the best measure, because the tree size was nearly constant over this period. For 'McIntosh' *Ferree* and *Schmid* (6) found the highest canopy efficiency on M9 followed by Ottawa 3 and M26, but with M27 much below. The very high efficiency for 'Summerred' in this experiment is in good agreement with results reported by *Preston* (8), where M27 was more efficient than M9 when measured as fruit to scion weight. Tree volume may be close related to the scion weight.

The very high volume efficiency for 'Summerred' on M27 and the lowest accumulated yields, show the typical problem with very dwarf rootstocks. The tree number must be very high to achieve the high yields one can expect by the efficiency. *Scholtens* (9) obtained a higher yield on M9 compared to M26 with a higher density for M9, but an even higher density for M27 did not bring higher yields. In this investigation the low yields on M27 are explained by a low cropping volume. Even with a high density you may not be able to exploit the high cropping potential shown for 'Summerred' on M27. The same relations exist between M26 and M9 in this investigation and was also shown by *Baarends* (2). Under field conditions the tree spread determines the tree density and the rootstock partly determines the tree shape and thus the canopy volume. With the same ground cover M26 gives a higher canopy volume than M9 and M27.

Burrknots

Koike and *Tsukahara* (7) found M26 to have a strong tendency for burrknot formation and after 5–6 years the rootstock surface was encircled. In this trial it was not possible to find any significant relationship between the number of burrknots and trunk size or the tree volume for 'Summerred'. However, all regression coefficients were negative.

For 'Spartan' this tendency was the same, but for rootstock M27, there was a significant negative relationship among the number of burrknots, tree volume and the trunk size.

In an analysis of covariance, burrknots indicated a significant influence on the tree vigour.

Some trees on M26 were badly attacked. Also *Baarends* (2) found more burrknots on M26 than on M9. Burrknots formation on above ground parts of M26 may be a problem. One way to avoid this problem is to place the union just above the soil level.

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Manuscript received 24 May, 1989.